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IN-FLIGHT TEMPERATURE ENVIRONMENTS OF JET FIGHTER AND ATTACK BOMBER AIRCRAFT INSTRUMENTATION

by

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ABSTRACT. Tests were conducted with two types of aircraft to determine the in-flight temperature environments of aircraft instrument indicators and sensors. The aircraft were squadron and research aircraft and were fully operational during the course of the tests. The cockpit instrument temperature test was conducted for a full year in two A4D-2N aircraft. The engine instrument sensor test was done in an F4H-1F aircraft for a two-month period. Conclusions from the tests show the cockpit to be a favorable environment for aircraft instrumentation, while the engine compartment exhibits a rather harsh environment.

U.S. NAVAL ORDNANCE TEST STATION

China Lake, California

December 1962

U. S. NAVAL ORDNANCE TEST STATION

AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

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WM. B. MCLEAN, PH.D. — *Technical Director*

FOREWORD

A study was initiated in 1960 at the U. S. Naval Ordnance Test Station to up-date the design requirements for aircraft instrumentation, and a tentative MIL-STD was drawn up. Intensive work was begun by the Station to verify the temperature parameters of these design requirements and to revise them where necessary. Maximum-temperature tests were conducted during a desert summer exhibiting near record solar radiation on parked aircraft with locked, sealed canopies. Minimum-temperature tests were conducted on an aircraft parked in the arctic during a record low-temperature winter. The work described in this report covers the in-flight phase of the test series, and indicates the temperature range to which aircraft instrument indicators and sensors are exposed during the normal, in-service life of an operational aircraft.

This work was supported by Task Assignment RREN-ST-307-216-0000-00-000. Data accumulated under Task Assignment RMMP-43-069/216-1/F012-03-014 were used also to complete the test program. This report has been reviewed for technical accuracy by Colin A. Taylor, Head, Product Evaluation Branch, and Eli Besser, Product Evaluation Branch.

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The author also wishes to thank the pilots of the Naval Air Facility, U. S. Naval Ordnance Test Station, China Lake, Calif., and the service representatives of the McDonnell Aircraft Corp. and the General Electric Co., whose cooperation made the engine-compartment portion of the tests possible.

Mention also should be made of Colin A. Taylor and Stuart O. Lilly, who have lent their continuing help throughout the extended test period.

INTRODUCTION

Aircraft instruments have advanced during the past years to a level of complexity that necessitates a closer study of the specifications to which the instruments are designed. The patterns used to establish the temperature parameters for the environmental testing of aircraft instrumentation have been pieced together over the years, and a study has been needed to indicate the validity of the accumulated temperature data. Instrument complexity demands that the general instrument location be treated separately rather than as a general category.

A major portion of the data used for the design of aircraft instrumentation has been obtained on propeller-driven aircraft. There are few propeller-driven aircraft left in the Fleet. This study, in effect, gives a basis for the comparison of these data and data obtained from jet-powered aircraft.

Testing has been done by the U. S. Naval Ordnance Test Station (NOTS) to ascertain the extreme temperature environments to which aircraft instruments would be exposed when the aircraft are parked on the desert during the summer and in the arctic during the winter (Ref. 7). These tests indicate only the worst possible environmental conditions. Aircraft built for service in the Fleet are not left idle for long periods of time. Before environmental temperature parameters can be assigned to any airborne system, the actual temperatures to which the system will be exposed during flight must be known.

This report is divided basically into two discussions: aircraft cockpit temperature environments and aircraft engine compartment temperature environments. The cockpit data were obtained from a year-long study because of the difficulty in predicting the most severe heat input, i.e., cockpit heater in the winter or solar insolation during the summer. The engine compartment test was of less duration because the heat input from the engine should be constant throughout the year.

PROCEDURE

AIRCRAFT AND LOCATIONS

Cockpit Tests. Two A4D-2N aircraft, BuNo. 145118 and 147788 (Fig. 1), were selected from Marine Attack Squadron VMA-211 for the tests. Each aircraft was assigned regular missions, as were the other noninstrumented aircraft of the squadron.

FIG. 1. A4D-2N Aircraft From VMA-211 Used in Cockpit In-Flight Test Series.

The aircraft of VMA-211 are deployed regularly on training missions around the southwest area of the United States. These missions take them from their home station, the El Toro Marine Corps Air Station, Santa Ana, Calif., to the U. S. Naval Ordnance Test Station, China Lake, Calif.; the Marine Corps Auxiliary Air Station, Vincent Field, Yuma, Ariz.; the Naval Auxiliary Landing Field, El Centro, Calif.; and the Naval Auxiliary Air Station, Van Voorhis Field, Fallon, Nev., all desert locations that provide higher-than-average environmental temperatures during the year. Santa Ana is located in the Los Angeles Basin, about 20 miles inland from the Pacific Ocean. Its mean temperatures are similar to those of the southern Basin region.

The cockpit tests were conducted for a full year, as it was not known whether the high summer temperatures or the direct impingement of hot air from the cockpit heating manifold would give the highest Btu input and, hence, the more severe temperature environment. (Heating from direct impingement is an individual condition that might have to be investigated in each type of aircraft.)

Engine Compartment Tests. One F4H-1F aircraft, BuNo. 143389, McDonnell Aircraft Corp. Production No. 4 (Fig. 2), was assigned for the tests. The aircraft is stationed at the Naval Air Facility, NOTS. The aircraft performed its regular research and development missions for other Station projects with the temperature-recording equipment installed internally. This temperature-recording equipment monitored the temperatures of the engine-compartment-mounted instrument sensors. The aircraft rarely flies far from the general area of the Mojave Desert; therefore, all data were collected in this region.

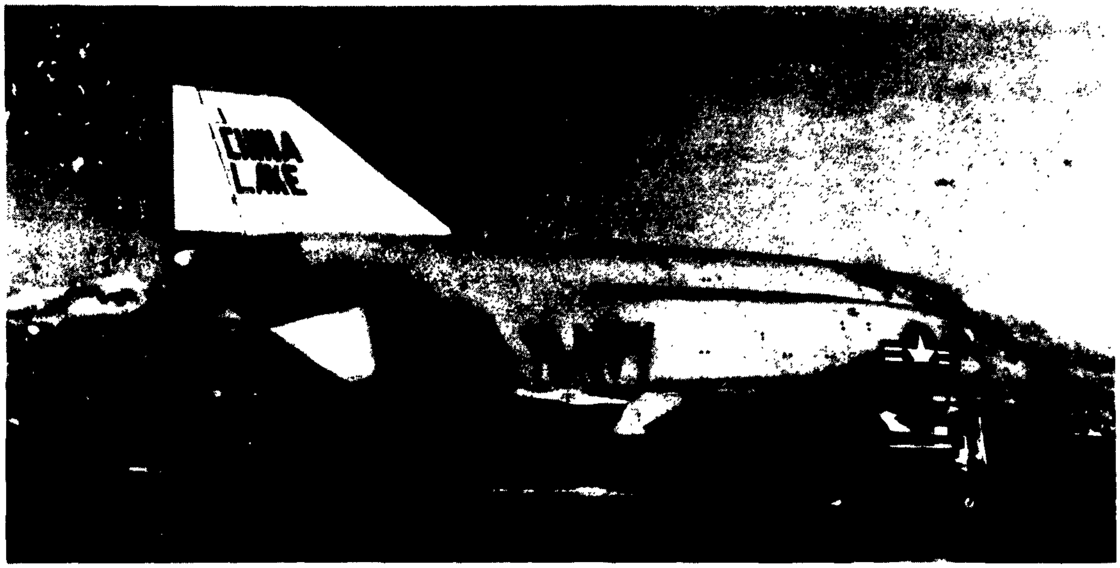


FIG. 2. F4H-1F Aircraft From NOTS, China Lake, Used in Engine Compartment In-Flight Test Series.

INSTRUMENTATION

Two basic modes of instrumentation were available for these tests: telemetry and an aircraft-contained recording system. Because telemetry is restricted to the range of the ground-installed receiving equipment with which it is associated, the airborne recording system seemed more flexible. As in most research projects, there was no industry-developed, "off-the-shelf" instrumentation package available to perform this recording task.

Cockpit. During the cockpit temperature test portion of the series, the entire recording unit (Fig. 3) was allotted a minor portion of the 22.5-inch-high, 28-inch-wide, and 32-inch-long forward baggage compartment of the A4D-2N aircraft. The "roof" of this compartment is the front underside of the jet engine. The prevailing atmosphere is one of jet fuel and hydraulic oil, and the unit had to be impervious to this severe environment. The unit was secured in the forward baggage hold so it would not break loose during flight or during rough treatment, such as on an aircraft-carrier landing or catapult takeoff.

The airborne recorder used in the A4D-2N aircraft was a Brown 20-point recording potentiometer converted by repackaging in an aluminum case. The final weight of the complete recording assembly was less than 70 pounds. Because of the cramped conditions, the chart reroll volume was reduced so that only one-half of a standard chart could safely be rerolled before removal of data from the system was

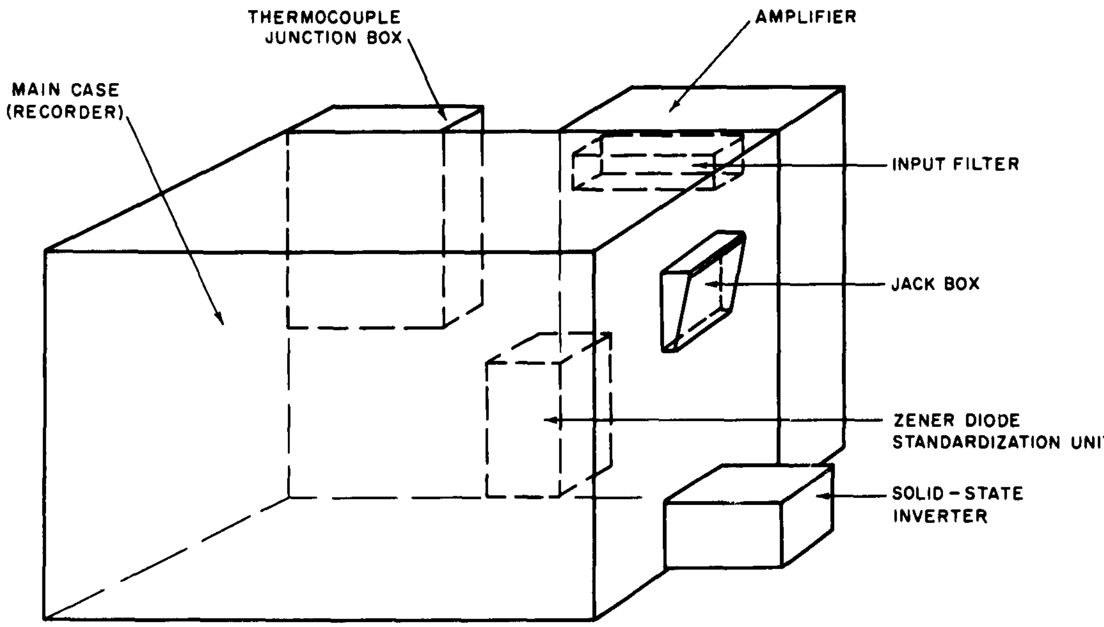


FIG. 3. Sketch of Airborne Recorder Assembly Used in A4D-2N Aircraft.

necessary. This usually was more than one month's data. The d.c. amplifier was mounted vertically in a self-contained unit attached to the back of the basic recorder unit. The Zener diode module and the power-input plug to the recorder's solid-state power-inverter filter assembly were mounted alongside the vertically mounted d.c. amplifier unit. The thermocouple junction box was installed next to the Zener diode unit, completing the back-mounted subassemblies. The solid-state power inverter used was an IT2106A (made by Electronic Research Associates, Inc.) mounted on the left side of the recorder box. The inverter-input filter was mounted inside the main case above the solid-state inverter.

To speed up any diagnosis of possible electronic trouble on the prototype instrument, a series of convenient test jacks was provided. This unit was mounted on the outside of the recorder case just above the solid-state inverter. The jack box provided a means of measuring the d.c. input into the inverter, the inverter a.c. output, and, following the input-voltage regulation, the recorder input a.c. voltage.

The cluster of component units was sealed together against the hydrocarbon-filled atmosphere with Minnesota Mining and Manufacturing Co.'s EC 1641 B potting compound and aviation-fuel tank sealing compound. The chart access door was gasket-sealed on installation or reinstallation of the data-gathering chart roll.

The original recorder was designed to operate on 110-volt, 60-cycle a.c. The combat-ready A4D-2N is equipped with both 115-volt, 400-cycle, three-phase a.c. and 28-volt d.c. Neither of these would directly operate the equipment. A unit was needed to convert either of these forms to the usable 60-cycle a.c. The IT2106A solid-state inverter was used, inverting the 28-volt d.c. to 110-volt, 60-cycle a.c.

The 28-volt d.c. bus bar on the A4D-2N aircraft is fed from the three-phase 400-cycle alternator through a three-phase rectifier. The rectified direct current is not filtered; therefore, it has a 3-volt peak-to-peak, 1,200-cycle ripple. The semiconductors in the solid-state inverter do not function properly when faced with this excessive ripple. To alleviate this situation, a filter assembly was installed between the aircraft power supply and the inverter.

The recorder unit was bolted securely to the mounting plate through a 1/8-inch-thick vibration-snubbing pad of fuel- and oil-resistant Hycar rubber. The mounting plate is a 1/4-inch-thick aluminum plate that is fitted as a semipermanent installation in the test aircraft.

Engine Compartment. During the engine-mounted instrument-sensor phase of the test series, the recorder was allotted the complete compartment in front of the stabilizer access (Compartment 64) of the F4H-1F aircraft. The mounting space in this location was more than adequate and provided a much cleaner environment than the location in the A4D-2N aircraft.

From experience obtained during the year-long cockpit instrument tests, the recorder was repackaged for the engine-mounted instrument tests in the F4H-1F aircraft (Fig. 4). Basically, the only change was the relocation of the subassembly modules to conserve space. The recorder box was made integral to eliminate 90% of the sealing problems

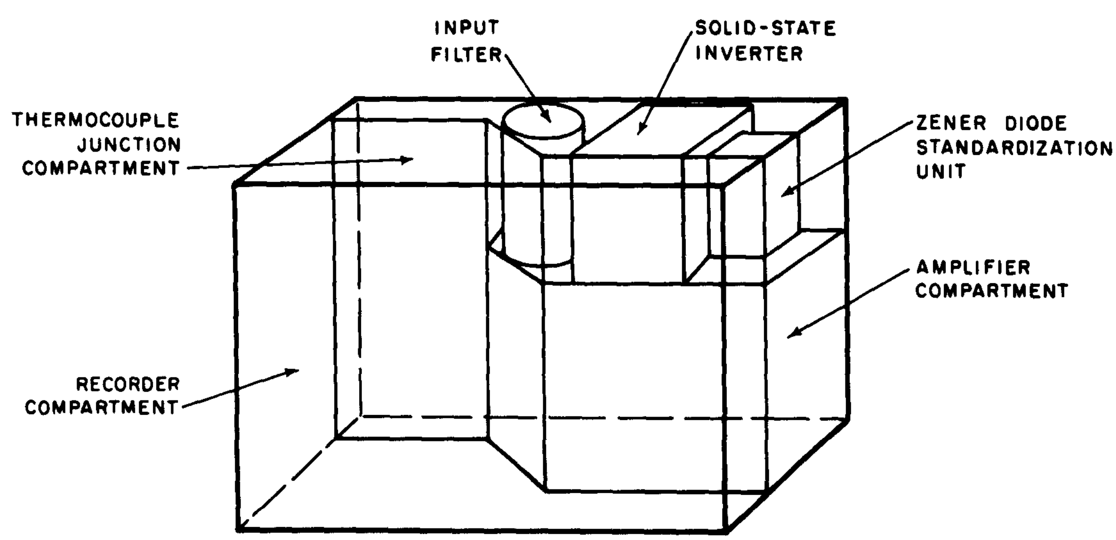


FIG. 4. Sketch of Airborne Recorder Assembly Used in F4H-1F Aircraft.

and to reduce further the outside dimensions of the instrument package. The chart reroll volume was expanded to allow a full chart to reroll before removal. The chart is accessible through the front door of the recorder. The other components, except the cold junction and units normally mounted on the chart-roll main casting, are reached through the rear door. They are removed by releasing eight quarter-turn fasteners. Sixteen of the 20 available information-channel cables were led outside the recorder during the engine compartment tests. They all were attached to the recorder through Amphenol plugs in the back of the recorder.

Pretesting of the Recorder. The converted recorder unit was placed in the altitude chamber at NOTS and subjected to an 80,000-foot equivalent altitude for one hour. No diverse reactions followed. After installation in an A4D-2N aircraft, the unit was subjected repeatedly to three to four times the force of gravity for almost 15 seconds during bomb-delivery practice, and seven to eight times the force of gravity briefly during arrested landings at El Toro.

The recorder was activated only during the time the pilot was in the aircraft. The A4D-2N aircraft is not battery equipped—its electrical system is only active when the main alternator is functioning after engine start-up. This selective operating time was acceptable for this test series only because of the static cockpit environmental tests previously conducted.

Thermocouples. Both the A4D and the F4H aircraft were instrumented with iron-constantan thermocouples consisting of a piece of copper 0.375 inch square and 0.005 inch thick, silver-soldered to the spread thermocouple wire ends. At each thermocouple location, the copper plate was formed to fit the surface of interest and held against the surface with glass tape. The flat plates averaged the temperature reading over the 0.375-inch square.

The thermocouple lead wires then were led directly through the aircraft back to the airborne recorder and soldered into an Amphenol plug. This plug attached directly to the recorder.

TEST PARAMETERS

COCKPIT

The results of the cockpit portion of these tests were obtained from a fairly typical distribution of events common to the operations of a land-based attack squadron. A typical day during training comprised about 1 to 5 hours flight time with the individual flights lasting about 0.5 to 2 hours or more, depending on the fuel load carried. The short flights usually are accompanied by a quick aircraft refueling and armament reloading, followed by another short flight. Under these conditions, the cockpit would have only a 10-minute maximum duration without the cabin-temperature control exerting its temperature-stabilizing effects. Table 1 shows a typical flight day while practicing weapon delivery.

TABLE 1. TYPICAL FLIGHT SCHEDULE FOR A4D-2N AIRCRAFT DURING COCKPIT INSTRUMENTATION TEST SERIES

Total activities, one day of flying.

Flight	Activity	Time duration, hr
1	touch-and-go	0.3
2	weapon delivery	0.7
(ground refuel)	....	0.2
3	weapon delivery	0.7
4	weapon delivery	0.8
5	altitude flight	1.1

The hours, or fractions thereof, are pilot-logged estimates of flight time. Considerable ground time can be included in the data without the pilot reporting it as flight time in the aircraft log. This unlogged time usually is used for ground checks and rearmament. The times recorded in Table 1 are estimated by the pilot from his wrist watch and not from a recording tachometer.

ENGINE COMPARTMENT

Flight time during the engine-compartment portion of the tests was somewhat different. Because the F4H aircraft used is a research vehicle, its flights were for specific purposes and could be from 0.2 to 1.8 hours. The maneuvers it performs are specifically called out by the project leader. The resulting demands on the aircraft can be severe.

PLACEMENT OF THERMOCOUPLES

Cockpit. The cockpit temperature data were obtained with thermocouples at the following locations in the A4D aircraft (Fig. 5):

Thermocouple no.	Distance from top of canopy, in.
1	17 1/2
2	23 1/2
3	32 3/4
4	40 1/4
5	48 1/4

It was evident from the unreduced data charts that at no time was the spread of temperature from the pilot's head level to the cockpit floor more than about 15°F. (The maximum-design temperature-gradient

FIG. 5. Thermocouple Locations in Cockpit of A4D-2N Aircraft.

requirements on an Air Force fighter cockpit can be only 20°F from the aircraft's floor to the pilot's head level. This checks rather well with the recorded temperature gradient under cockpit heater-controlled conditions.)

Engine Compartment. The engine-mounted instrument-sensor temperature data for the right-hand engine compartment were obtained with thermocouples at the following locations in the F4H aircraft (see Fig. 6 for general locations):

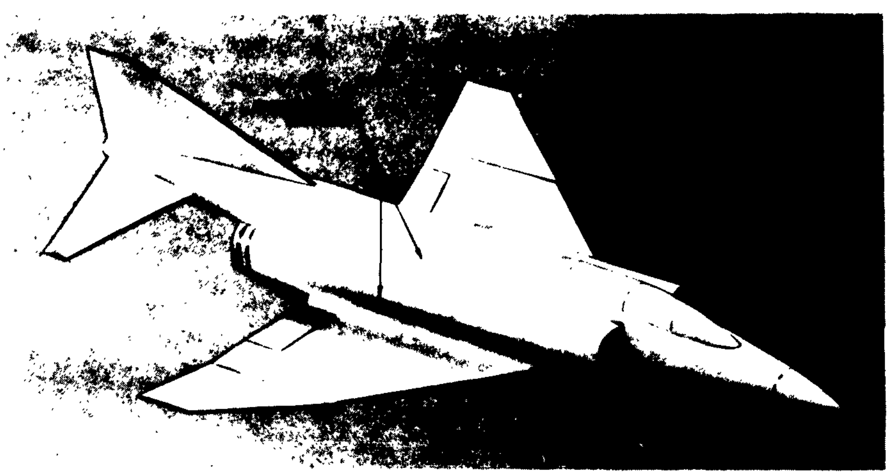


FIG. 6. General Thermocouple Locations in Engine Compartment of F4H-1F Aircraft.

1. In the air, on the keel side near the rear engine mount
2. On the tachometer generator, away from the engine
3. On the tachometer generator, next to the engine
4. In the air, between the tachometer generator and the fuselage
5. On the oil pressure transmitter, away from the engine
6. On the oil pressure transmitter bracket, next to the engine
7. In the air, near the oil pressure transmitter
8. In the air, 2 feet aft from the oil pressure transmitter

Temperature data for the left-hand engine compartment were obtained at the following locations:

9. On the fuel pressure transmitter (for the right-hand engine)
10. On the fuel pressure transmitter (for the left-hand engine)
11. In the air, between the left-hand fuel pressure transmitter and the 17th-stage bleed-off line
12. On the tachometer generator, next to the engine
13. In the air, aft of the tachometer generator
14. On the oil pressure transmitter rear fittings
15. In the air, between the oil pressure transmitter and the engine
16. In the air, between the oil pressure transmitter and the keel

Miscellaneous Thermocouples. Four other thermocouple locations were used during the tests for check information:

1. Inside the amplifier compartment of the recorder unit
2. Inside the recorder main compartment, near the solid-state inverter and cold junction of the instrument
3. Inside the thermocouple-junction compartment in the recorder assembly
4. In the air of the forward baggage compartment or aft compartment in which the recorder was mounted

The last series of thermocouples was used to delineate individual flights when they were spaced so closely that the cockpit or engine temperature did not change from completion of the first flight to the start of the second. In this case, the amplifier would cool enough during these quick turnarounds to register a reading. During a typical winter 10-minute turnaround, this thermocouple sensed a 10°F temperature drop. When the forward baggage compartment is "unbuttoned," the amplifier temperature drops 20°F in about 5 minutes. It could be seen that the aluminum amplifier and recorder cases diffused excess thermocouple-sensed heat from the amplifier to the atmosphere rather quickly, giving a good indication of when the aircraft had completed any given mission.

The divergence of the amplifier thermocouple print on the original chart gave a quick check of the records' validity. The recorder's amplifier dissipates heat in excess of that of other measured points in this test installation and will record maximum temperatures. This fact gives a quick check on the recorder's sensitivity, because the unit is called on to jump from near 0°F in the forward baggage compartment to 130°F or more at the amplifier many times during each recorder print cycle. If the instrument is sluggish or malfunctioning, the chart will indicate this readily.

In addition to the thermocouples installed in the F4H aircraft, temperature "tattletale" indicators[1] were mounted as follows:

No.	Range, °F	Location
1	200–350	Left-hand oil pressure transmitter shield
2	350–500	Left-hand oil pressure transmitter shield
3	200–350	Near secondary wing span on side bulkhead aft of engine mount
4	350–500	Near secondary wing span on side bulkhead aft of engine mount
5	200–250	Forward end of airborne recorder in Compartment 64

The tattletale consists of a series of chemical dots that change color at a specified temperature. Usually, there are four dots per strip. In the case of the 200–350°F strip, the dots respond to 200, 250, 300, and 350°F. On the 350–500°F strip, the response is at 350, 400, 450, and 500°F. It can be seen that these indicators, by themselves, give only temperature-level information and not time-duration statistics. They are, however, a good check on the accuracy of the airborne recorder. They also would be of value in locations where thermocouple wires could not be installed.

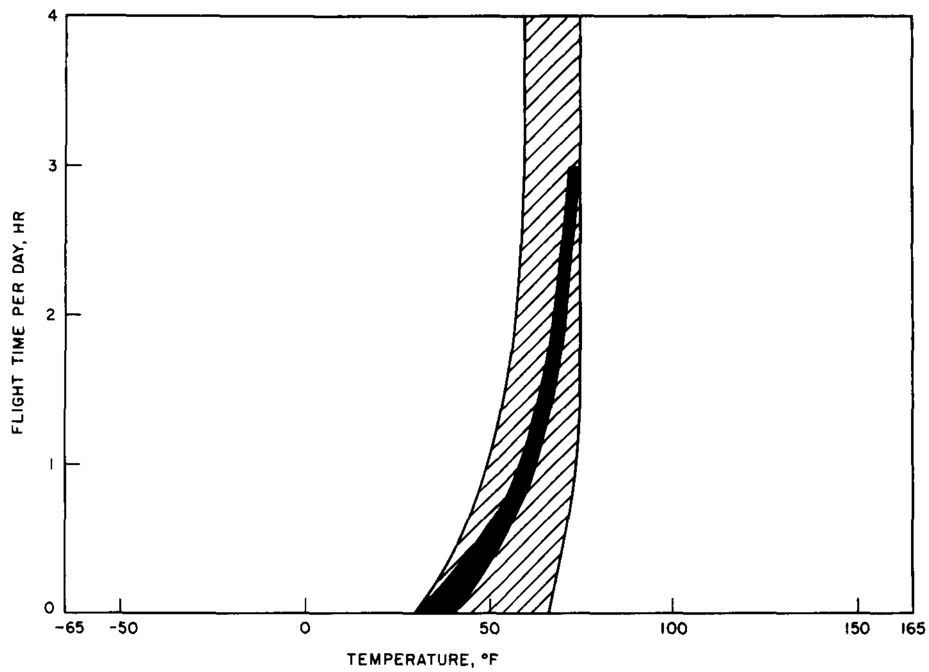
RESULTS

COCKPIT TESTS

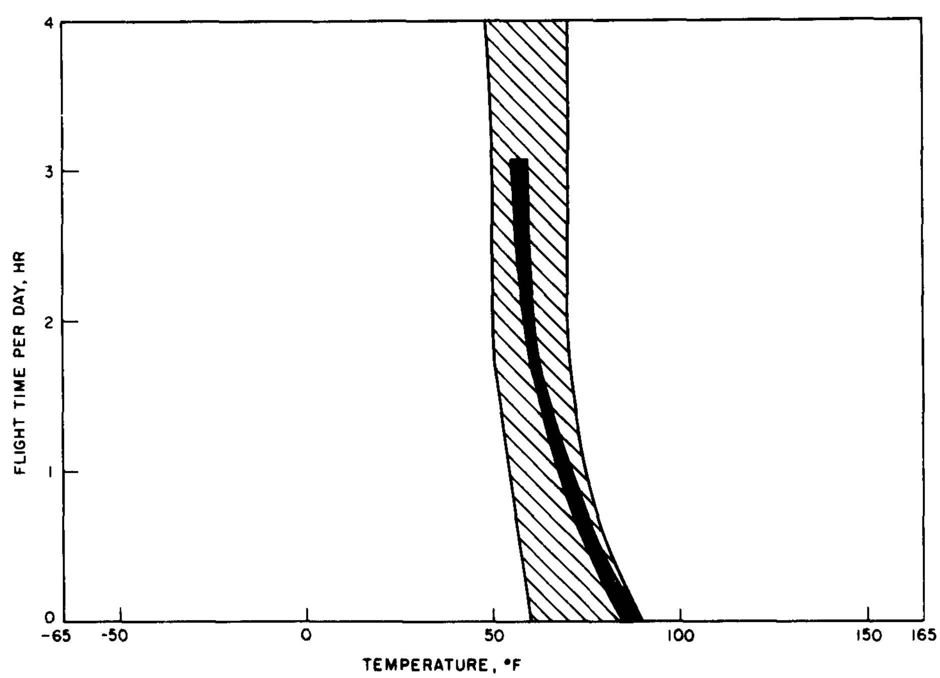
The solid band in Fig. 7a depicts temperatures recorded in the cockpit, under the top of the canopy at the pilot's head level, during one flight day in January 1961. At the beginning of the day, the temperature was 32°F, but, after 1 hour, the temperature had risen to 69°F, a rise of 37°F. This is much less than 1°F/min; therefore, there should be no shock to the installed aircraft instruments. Data recorded for a flight day during the summer (Fig. 7b) show the beginning flight temperature to be 90°F. The temperature 1 hour later was 70°F. The temperature differential would be, in this case, 90°F – 70°F = 20°F drop/hr.

In Fig. 7a and 7b, the in-flight cockpit data are combined into two typical, averaged seasonal bands. The chart readings were segregated by days and flights, and each day was plotted by composite flight-hours per day to give the inclusive band of recorded temperature for that season. The solid band within the seasonal results indicates the typical day during the test series where the most extreme temperatures were recorded. The typical-day temperatures were controlled by only one pilot; the composite seasonal bands are the desired cockpit temperatures chosen by the many pilots who operated the aircraft and its equipment during the season.

[1] Tem-plate brand tattletales, obtained from Pyrodyne, Inc., Los Angeles, Calif., were used.



(a) Winter temperature spread. Solid section represents coldest day.



(b) Summer temperature spread. Solid section represents hottest day.

FIG. 7. Comparison of Winter and Summer Temperature Spreads in Cockpit of A4D-2N Aircraft During Flight Conditions.

It is interesting to note the general shape of the seasonal temperature bands. They resemble the letter J, with the winter seasonal band being a normal J, and the summer seasonal band being the mirror image. This indicates the stabilizing effect of flight time that allows the cockpit conditioning equipment to control the temperature of the cockpit-mounted instruments. This is the case for non-heat-generating instruments only. Self-heating instruments, of course, should reach higher temperatures.

ENGINE COMPARTMENT TESTS

A current problem associated with the F4H aircraft was taken into consideration during the engine compartment tests. Failure of the oil pressure transmitter on the J79-8 engines because of loose solder bonds has caused considerable grounding of the aircraft. From visual observation, it was noted that the loosened solder joints indicated a cold working process had taken place. Knowing that the 50-50 solder used in the oil transmitter bonds melts at 437°F, it was determined that the temperature inside the engine compartment could not have been over 450–500°F.

The F4H aircraft used during these tests was equipped with J79-2 engines, which had not shown the oil pressure transmitter problems that the J79-8 engines had. This aircraft, however, was equipped with a prototype shroud on the left-hand engine that was being used in conjunction with Station research projects. This shroud tended to aggravate any overheating situation, and the aircraft had lost three oil pressure transmitters because of this effect. To offset this, a radiation shield had been installed between the engine and the oil pressure transmitter. It was decided to instrument the oil pressure transmitters on both the shielded left-hand and unshielded right-hand engines and record the temperature extremes at these points. Figure 8 shows the results of the worst exposure recorded from the instrumented oil pressure transmitters. Curves are given for the shielded oil pressure transmitter on the left-hand engine and the unshielded oil pressure transmitter on the right-hand engine. Note that in the rapid climb to altitude during the first minutes of flight, the oil pressure transmitter on the right-hand engine reached a peak temperature of 410°F. During this same period, the shielded oil pressure transmitter on the left-hand engine reached only 228°F. At the 410°F temperature, the oil pressure transmitter on the right-hand engine was only 27 degrees away from the melting point of the 50-50 solder. The combination of this temperature and the engine vibration could have cold worked the solder joint and caused failure of the sensor. The shielded sensor, however, is about 50% cooler and would not be subjected to this combined temperature–vibration action.

During this 100-minute flight, the tachometer generator showed no temperature above 170°F. The unshielded fuel boost transmitter in the shrouded left-hand engine compartment, however, followed the temperature rise of the right-hand oil pressure transmitter. Its peak temperature was 353°F after 25 minutes of flight; the temperature then

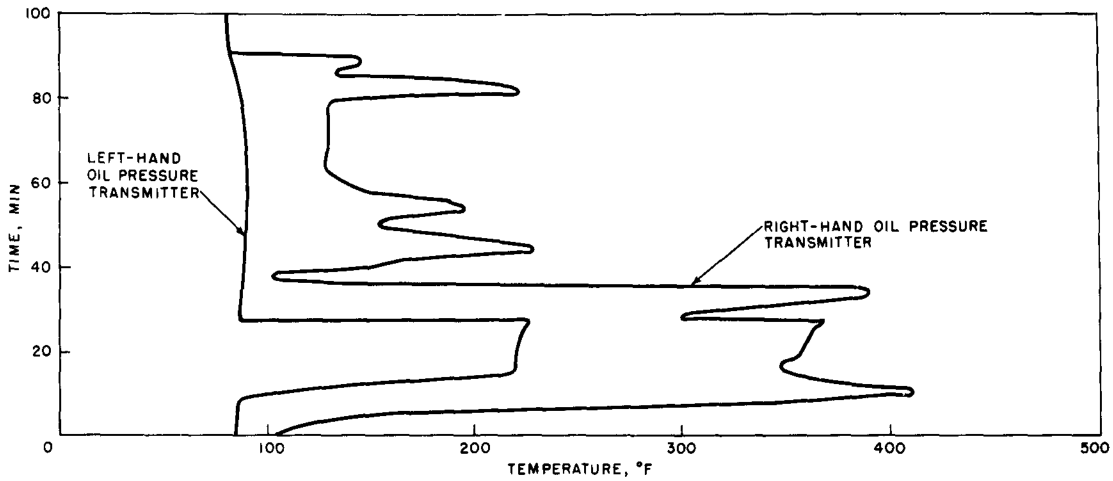


FIG. 8. Temperature Curves of Shielded Left-Hand Oil Pressure Transmitter and Unshielded Right-Hand Oil Pressure Transmitter in F4H-1F Aircraft.

dropped abruptly to about 100—150°F, where it remained for the rest of the flight. The cooling air between the tachometer generator on the right-hand engine and the aircraft fuselage also followed this high-temperature trend, reaching a peak temperature of 360°F after 27 minutes of flight.

The highest temperature recorded during this flight was 534°F. This temperature was measured on the keel of the aircraft inside the right-hand engine compartment about 1 foot forward of the engine mount. This location is much further aft than the location of any engine-mounted instrument sensor, with the exception of the tail pipe temperature-indicator thermocouples.

It should be noted that during this flight, which exhibited the most extreme temperatures of the series, the peak temperatures at the instrument sensors subsided drastically after the aircraft had completed the climbing maneuvers to gain altitude. Once at altitude, the temperatures at the sensor locations in the engine compartments leveled off. Subsequent maneuvering by the aircraft caused periodic temperature rises, but no sustained high temperature conditions were noted. It should be especially noted that the radiation shield mounted on the oil pressure transmitter of the left-hand engine negated all drastic temperature rises during all maneuvering phases of the flight.

During the 2-month testing period, data were obtained from flights of the F4H aircraft. The most extreme temperatures were recorded during the flight mentioned above. The other flights gave data that showed no sustained in-flight instrument-sensor temperature above 173°F.

CONCLUSIONS AND RECOMMENDATIONS

COCKPIT

The aircraft cockpit is a well protected environmental chamber. Not only is it thoroughly shielded by the aircraft skin and canopy but it is temperature-controlled any time a pilot is in the cockpit. This is true for any climate or season. Figures 7a and 7b show the cockpit's temperature to equalize at about 60–70°F in both winter and summer.

It is concluded that cockpit-mounted aircraft instruments will seek the same temperature the pilot sets for his personal comfort in the aircraft's cockpit. The instrument panel got no hotter than a recorded temperature of 90°F during the test period, except twice, when one pilot decided he preferred 100°F for his controlled cockpit temperature. This was quickly rectified when the pilot released the aircraft to another pilot who simply turned off the cockpit heat. (The 100°F cockpit temperature seems quite reasonable in light of the practice of desert dwellers during the summer months. The air conditioning in most homes is set to hold a cool house at about 80°F when the outside temperature is at 100–110°F. If the indoor temperature drops below 75°F, it is uncomfortably cold; outdoors, it is uncomfortably hot. Therefore, the Marine pilot must have decided that 100°F was a comfortable cockpit temperature during August in the desert.)

Previous to the tests mentioned herein, cockpit environmental tests gave warnings of possible extreme elevated temperatures to the magnitude of 181 or 217°F. At no time during the program discussed herein were such temperature extremes even approached. This can be attributed to the small exposure time during which these elevated temperatures were experienced and the avoidance of locked, sealed canopy conditions while the aircraft were parked on the runway. The maximum cockpit temperature of 90°F recorded during this test series is far below the present qualification temperature of 160°F.

The present design requirement for cockpit-installed aircraft instruments is -80°F for 48 hours (2 full days) and 160°F for 24 hours. In light of the static environmental results reported in Ref. 7, and the results from the work reported herein, it would seem that both are too severe. The lower limit of -80°F should be raised to -40°F. The time duration of 48 hours should be adequate if the soak temperature is -40°F, but if -80°F is retained, the time of soak should be reduced drastically. As was reported in Ref. 7 (see Fig. 48 of this reference), the probability of reaching or exceeding -40°F during any month of the year in the arctic is about 4% in December, 5% in January, 3% in February, 0.25% in March, and nil during the rest of the year. These in-flight tests indicate that at any time the aircraft is manned, the cockpit instrumentation will be far from the -40°F level. The upper temperature limit of 160°F should be reduced to no more than 130°F. The static open-cockpit data given in Ref. 7 show that 130°F is about the highest temperature expected during summer exposure. The in-flight data show 130°F to be a more than adequate qualification temperature. The above recommendations are for non-heat-producing instruments. If the instrument is heat-producing, it is recommended that the unit operate satisfactorily in the 130°F environment.

ENGINE COMPARTMENT

The engine compartment of a jet-powered aircraft exhibits a harsh, severe environment for precision instrument sensors. Heat is transmitted to these instruments through all three heat-transfer modes. The comparison of the right-hand oil pressure transmitter curve and the maximum temperature recorded on the left-hand fuel boost transmitter (Fig. 8) indicates that radiant heat is the major problem encountered in the environment of engine compartment instrument sensors, the cause of the failures to instrument sensors that have been experienced in the F4H aircraft, and the major factor to be considered in the design of these sensors. It would seem that, instead of designing instrument sensors that are larger, heavier, and able to withstand the high radiant temperatures themselves, serious consideration should be given to the use of heat sinks, radiation shields, and insulation to offset this heat problem. It should be noted that a thin shield of 20-gage aluminum can provide an environmental protection so that a Class II instrument sensor can perform adequately in a Class IV basic environment.

NEGATIVE NUMBERS OF ILLUSTRATIONS

FIG. 1, LHL L061660
FIG. 2—4, none
FIG. 5, LHL L066557
FIG. 6—8, none

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